Is Economic Liberalization causing Environmental Degradation in India? An Analysis of Interventions

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2014

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India's fossil fuel based energy-led economic growth and carbon emissions are largely influenced by economic liberalization. In this paper, we have considered twenty years before and after liberalization (1971-2010) and by formulation of an error correction model, we have demonstrated how causal associations among economic growth, drivers of growth, and negative consequences of growth undergo changes based on three constructs, namely industrialization, energy efficiency, and rural-urban migration. Analysis of missing feedback link in Environmental Kuznets Curve hypothesis using contextual interventions is the primary contribution of this paper in ecological economics literature.

INTRODUCTION

Association between global climatic shift and atmospheric emission level has been a topic of interest for researchers around the world for a stint period. Considering the greenhouse gas (GHG) emissions around the world, carbon dioxide (CO_2) emission from fossil fuel combustion accounts to nearly 57 percent of the entire GHG emission (Intergovernmental Panel on Climate Change, 2007). Moreover, considering the atmospheric lifetime of GHGs, CO_2 can be considered as more harmful than sulphur dioxide (SO_2) or nitrogen dioxide (NO_2), because atmospheric lifetime of CO_2 is as high as 30-95 years (Jacobson, 2005), in comparison with a day to two weeks' atmospheric lifetime of SO_2 (Prospero, 2002), or less than a day in case of NO_2 (Beirle, Platt, Wenig & Wagner, 2003). The economic growth that India has achieved over last two decades is a result of fossil fuel based energy consumption (Cheng, 1999). From this perspective, reduction in electricity consumption can in turn reduce the level of atmospheric emission of GHGs. However, this uncomplicated solution is unrealistic in nature, as it may cause harm to the economic growth pattern, as a developing nation like India, cannot resort to such alternatives. Consequently, researchers across the world are looking for a sturdy solution to this problem, before the situation goes out of hand.

If we look at the patterns of ongoing and existing research in this domain, we can categorize them into three distinct categories, which we will discuss one by one. While reflecting on the association between environmental degradation and economic growth, the first and foremost hypothesis, which was

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mostly discussed by researchers, is Environmental Kuznets Curve (EKC) hypothesis. After Kuznets (1955) found inverted U-shaped curvilinear association between income inequality and economic development, Grossman and Krueger (1991) have found its resemblance, while establishing an association between environmental degradation and economic growth in a free trade regime, and they have coined the term "Environmental Kuznets Curve". Later on, the study on EKC hypothesis was carried out by several researchers in diverse contexts (Hayami & Ruttan, 1970; Shafik & Bandyopadhyay, 1992; Antle & Heidebrink, 1995; De Bruyn, van den Bergh & Opschoor, 1998; Hill & Magnani, 2002; Dinda, 2004; Klump & Cabrera, 2008; Kijima, Nishide & Ohyama, 2010 along with others). Nevertheless, these studies failed to reach a consensus regarding reaching the turnaround point of EKC, and with graduation of time, they were proved out to be questionable in nature.

The second category of research in this field is to formulate a bivariate framework to analyze the association between economic growth and drivers of economic growth, which most of the researchers have identified as energy consumption, electricity consumption, or fossil fuel consumption. This category of research was the first to find out the missing feedback link in EKC hypothesis, which was silent about what can possibly be the negative consequences of environmental degradation on economic growth, in terms of the drivers of achieved economic growth. In this category, the first study was carried out by Kraft and Kraft (1978), who introduced GNP as an indicator of economic growth, while considering the causal association between energy consumption and economic growth of U.S. for 1947-1974. They have found the causal association running from GNP to energy consumption. Subsequent to that, research in this direction was carried out in several contexts, like, for U.S. (1947-1979) by Yu and Hwang (1984), for Tanzania (1960-81) and Nigeria (1960-84) by Ebohon (1996), for India (1955-1990), Pakistan (1955-1990), Indonesia (1960-1990), Malaysia (1955-1990), Singapore (1960-1990), and Philippines (1955-1991) by Masih and Masih (1996), for G-7 countries (1950-1992) by Soytas and Sari (2003), for Bangladesh (1971-1999) by Mozumder and Marathe (2007), for China (1971-200) by Shiu and Lam (2004) are few among those. With graduation of time, this bivariate framework was starting to gain obsolesce, and in place of that, multivariate framework of this feedback analysis was gaining significance, like, for U.S. (1974-1990) by Yu and Jin (1992), for Israel (1973-1994) by Beenstock, Goldin and Nabot (1999), for India (1973-1995), Indonesia (1973-1995), Thailand (1971-1995), the Philippines (1971-1995) by Asafu-Adjaye (2000), for Greece (1960-1996) by Hondroyiannis, Lolos and Papapetrou (2002), for India (1907-2000) by Ghosh and Basu (2006) to name a few. Ozturk (2010) has provided with an extensive literature survey on the nexus between economic growth and energy / electricity consumption. Though divergent results exist considering diverse contexts, the literature mostly shows the evidence that there is an unexplained feedback link between economic growth and drivers of economic growth, with respect to the background of EKC hypothesis.

As an extension of the previous category of research, the third category of research had emerged, in which the missing feedback link of EKC hypothesis has been analyzed in a new direction. In this category of research, nexus between GHG emission, economic growth, and the drivers of growth has been analyzed by several researchers. Nordhaus (1977) stated that ignition of fossil fuels brings about emissions of CO_2 into the atmosphere, and it stays in the atmosphere for a long while. Owing to the discerning assimilation of emission, the amplified atmospheric accumulation brings about augmented global temperature. This was empirically verified by other researchers as well (Manabe & Wetherald, 1975; Wetherald & Manabe, 1988). In a study of an uneven panel data of 130 countries for 1951-1986, Holtz-Eakin and Selden (1995) have found out that growth in annual emission level will continue at a rate of 1.8% up to 2025. Moreover, in countries with lower per capita income GHG emission rises because of growth in population and industrial development. Later on, studies on this perspective were carried out in several contexts. Kander (2002) attributes energy consumption as the reason behind CO_2 emission growth in Sweden, for 1800-2000. Frankel and Rose (2005) have established that trade openness and democracy have positive effect on environmental quality by lowering atmospheric emission level. Soytas, Sari and Ewing (2007) have established a causal association between CO_2 emission growth and growth in energy consumption in United States, for 1960-2004. Zhang and Cheng (2009) have established a causal association between CO_2 emission growth and growth in energy consumption in China, for 1980-2007.

Halicioglu (2009) has established the same in case of Turkey for 1960-2005. Chang (2010) has established that economic growth, which leaves apart other social aspects, results in increase in fossil fuel based energy consumption, and thereby CO_2 emission.

This paper investigates causal association between fossil fuel consumption, economic growth, and CO_2 emission, using the interventions of industrial value added, energy waste, and urbanization. Span of the study has been taken as 1971-2010, as it covers twenty years before and after economic liberalization. Global rank of India as the third highest energy consuming country after China, the U.S. and fourth highest CO_2 emitting country after China, the U.S. and the European Union, makes itself an obvious choice as a context of this study. Although Sinha and Mehta (2014) have identified that CO_2 emission and economic growth holds a bidirectional causal association for India, devoid of testing this association being linked with fossil fuel consumption and associating this causality with India's economic liberalization perspective, may leave out several policy implications, which may prove out to be significantly consequential considering India's stand regarding environmental degradation. Choice of interventions for this study has been done keeping in mind the economic liberalization perspective of India, and the chosen interventions are (1) industrial development, for which industrial value added has been taken as proxy, (2) energy efficiency, for which combustible energy waste been taken as proxy, and (3) urban development, for which urbanization has been taken as proxy. These interventions can have possible effect on the causal associations to be estimated, at several levels. Likewise, industrial development can have effect on all the causal associations, energy efficiency can have effect on the causal associations concerning fossil fuel consumption, and urbanization can have effect on the causal associations concerning economic growth and CO_2 emission. We have analyzed the causal associations between fossil fuel consumption, economic growth, and CO_2 emission, before and after applying the interventions. Data has been taken from country-level indicators of the World Bank database. In the subsequent sections, we will discuss about the econometric methodology, analysis of the data, and conclusive policy implications.

ECONOMETRIC METHODOLOGY

In this section, we will discuss about the econometric methodologies applied to look into the association between fossil fuel consumption, economic growth, and CO_2 emission, applying economic liberalization related interventions. To start with, we should check the integration characteristics of the data. For this purpose, unit root tests have been applied. If variables in the dataset are I(1) in nature, then cointegration test is used to look into the long run equilibrium association among them. Based on the findings of aforementioned test, order of integration will be found, and that will ensure the applicability of error correction model (ECM), based on which directions of causality among the variables are found. In the subsequent sections, we will discuss these methodologies one by one.

Investigation For Integration

In most of the cases, time series economic data exhibits non-stationary nature, as their central tendencies are found to be upwards over a long period. However, in order to investigate the considerable long run association among the variables, carrying out non-stationarity test becomes essential. This test primarily focuses on order of integration, at which point considered variables become stationary in nature. The test is carried out on the level data, and subsequently on differentiated forms of the variables. For this purpose, we will apply augmented Dickey-Fuller test (Dickey & Fuller, 1981), Phillips-Perron test (Phillips & Perron, 1988), and Kwiatkowski-Phillips-Schmidt-Shin test (Kwiatkowski, Phillips, Schmidt & Shin, 1992). These three tests will be conducted for checking the serial correlation, heteroscedasticity, and deterministic trend present in variables under consideration. Following are the test statistics considered for each of the cases:

Augmented Dickey-Fuller (ADF) test: $$\left(\frac{\sigma^2}{\lambda^2}\right)^{1/2} . t_{\pi=0} - \frac{1}{2}\left(\frac{\lambda^2-\sigma^2}{\lambda^2}\right)\left(\frac{T.SE(\pi)}{\sigma^2}\right) \tag{1}$$

Phillips-Perron (PP) test: $T\pi - \frac{1}{2}\left(\lambda^2 - \sigma^2\right)\left(\frac{T^2.SE(\pi)}{\sigma^2}\right)$ (2)

Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test: $\left(T^{-2}\sum_{t=1}^{T} S_t^2\right) / \lambda^2$ (3)

Where, $\sigma^2 = \lim_{T\to\infty} T^{-1}\sum_{t=1}^{T} E\left[u_t^2\right]$ (4)

$$\lambda^2 = \lim_{T\to\infty}\sum_{t=1}^{T} E\left[T^{-1}S_t^2\right] \quad (5)$$

$$S_t = \sum_{t=1}^{T} u_t \quad (6)$$

Investigation for Cointegration

Cointegration is an econometric methodology to investigate the subsistence of long run equilibrium association among variables. This is imperative from an algebraic perspective, as progression of the variables over a long timeframe adjusts the inconsistencies being appeared along the shorter durations. In accordance with Dickey, Jansen and Thornton (1991), if the cointegrated association among variables is not present or weak in nature, then probability of existence of variability in their long-term movement is very high. In view of the existence of this cointegrated association among variables, conducting a regression analysis becomes significant. However, for any number of non-stationary time series variables to be cointegrated, it is imperative for their linear combination to be stationary in nature (Engle & Granger, 1987). However, it is seemingly not appropriate to stick to a methodology, which is capable of analyzing the cointegrated association between only two variables. That is the reason behind our preference of the cointegration testing methodology by Johansen and Juselius (1990) over the one that of by Engle and Granger (1987), as scope of our analysis is not confined by bivariate nature of analysis. Trace and maximum eigenvalue statistics are the two major components of this cointegration analysis (Johansen, 1988, 1991). We will discuss about both of these two statistics.

Consider Y_t as an (n X 1) vector of I(1) integrated variables and ε_t as an (n X 1) vector of error terms. Then the vector autoregressive model (VAR) of order N can be expressed as per the following:

$$\Delta Y_t = \mu + \Pi\Delta Y_{t-1} + \sum_{i=1}^{N}\Gamma_i \Delta Y_{t-i} + \varepsilon_t \quad (7)$$

Where, $\Pi = \sum_{i=1}^{N} A_i - \mathrm{I}$ (8)

$$\Gamma_i = -\sum_{j=i+1}^{N} A_j \quad (9)$$

Precisely, $\prod$ contains the information about coefficients, which determine the nature of long run association among variables under consideration. Rank of this matrix, which determines number of cointegrating vectors among variables, is calculated through two statistics, namely trace and maximum eigenvalue. The trace test embarks upon the null hypothesis of having cointegrating vectors equal to the rank of the matrix (say r) aligned with the alternate hypothesis of having cointegrating vectors of number n (< r). In case of the maximum eigenvalue test, it embarks upon null hypothesis of having cointegrating vectors equal to the rank of the matrix (= r) against the alternative hypothesis of having cointegrating vectors exactly one more than the rank of the matrix (= r + 1). The test statistics are as per the following:

Trace statistics (JJ_T) = $-T\sum_{i=r+1}^{n}\ln(1-\eta)$ (10)

Maximum eigenvalue statistics (JJ_{ME}) = $-T\ln(1-\eta_{r+1})$ (11)

Where, η = i[th] principal canonical correlation

Investigation for Causality Association

In this section, we will make use of Granger causality test (Granger, 1969) to investigate the causal association encompassing parameters. The quadrivariate Granger causality test based on error correction model (Toda & Phillips, 1993) can be formulated in the following manner:

$$\begin{bmatrix}\Delta\ln FF_t\\ \Delta\ln EG_t\\ \Delta\ln CE_t\\ \Delta\ln IN_t\end{bmatrix}=\begin{bmatrix}a_1\\ a_2\\ a_3\\ a_4\end{bmatrix}+\begin{bmatrix}b_{11,1}&b_{12,1}&b_{13,1}&b_{14,1}\\ b_{21,1}&b_{22,1}&b_{23,1}&b_{24,1}\\ b_{31,1}&b_{32,1}&b_{33,1}&b_{34,1}\\ b_{41,1}&b_{42,1}&b_{43,1}&b_{44,1}\end{bmatrix}\begin{bmatrix}\Delta\ln FF_{t-1}\\ \Delta\ln EG_{t-1}\\ \Delta\ln CE_{t-1}\\ \Delta\ln IN_{t-1}\end{bmatrix}+\dots$$
$$+\begin{bmatrix}b_{11,n}&b_{12,n}&b_{13,n}&b_{14,n}\\ b_{21,n}&b_{22,n}&b_{23,n}&b_{24,n}\\ b_{31,n}&b_{32,n}&b_{33,n}&b_{34,n}\\ b_{41,n}&b_{42,n}&b_{43,n}&b_{44,n}\end{bmatrix}\begin{bmatrix}\Delta\ln FF_{t-n}\\ \Delta\ln EG_{t-n}\\ \Delta\ln CE_{t-n}\\ \Delta\ln IN_{t-n}\end{bmatrix}+\begin{bmatrix}\lambda_1\\ \lambda_2\\ \lambda_3\\ \lambda_4\end{bmatrix}\left[ECT_{t-1}\right]\begin{bmatrix}\varepsilon_1\\ \varepsilon_2\\ \varepsilon_3\\ \varepsilon_4\end{bmatrix} \quad (12)$$

Where, FF stands for fossil fuel consumption, EG stands for economic growth, and CE for CO_2 emission, and IN stands for interventions. ECT_{t-1} is the lagged error correction term, and ε_1, ε_2, ε_3, and ε_4 are reciprocally exclusive white noise residuals.

ANALYSIS

Before Applying Any Intervention

Analysis of collected data starts with checking the stationarity nature of variables under consideration, for which unit root tests have been conducted. The results of unit root test are recorded in Table 1. It can be visualized that the level data show no indications of stationarity, which confirms existence of unit roots in all three variables under consideration. Subsequently, we moved towards differencing them and conducting unit root tests on the differentiated variables. It is evident from the results that all the three variables are showing stationary nature after first differentiation. This result also confirms that the variables are integrated to order one, i.e. I(1) in nature.

TABLE 1
UNIT ROOT TEST RESULTS

		ADF	*PP*	*KPSS*
Level				
Intercept	FF	-1.033828	-0.988481	0.759594
	EG	0.501026	0.383000	0.769768
	CE	-0.699015	-0.753285	0.779263
Intercept and Trend	FF	-0.642654	-0.824338	0.159340
	EG	-0.822281	-1.177163	0.109605
	CE	-1.685673	-1.685673	0.163886
First Difference				
Intercept	FF	-2.674129[b]	-5.501225[a]	0.243062

	EG	-5.492174[a]	-5.583894[a]	0.201027
	CE	-6.523463[a]	-6.522925[a]	0.131064
Intercept and Trend	FF	-5.598336[a]	-5.585270[a]	0.146613
	EG	-5.468922[a]	-5.505470[a]	0.173178
	CE	-6.481731[a]	-6.480215[a]	0.076280

[a] Value at 1% significance level
[b] Value at 5% significance level

Once it has been established that the variables are integrated of order one, it is needed to test the cointegration association between them. The cointegration testing methodology by Johansen and Juselius (1990) have been applied on the variables. The results are recorded in Table 2. The results show that a brawny long run association subsists among the variables. Null hypotheses of having no cointegrating vectors have been rejected by both the statistics, and they show that two cointegrating vectors are present between the variables. Based on these results, we can proceed for further analysis.

TABLE 2
COINTEGRATION TEST RESULTS

Trace test				*Maximum Eigenvalue test*			
Null	*Alternate*	JJ_T	*Critical Value*	*Null*	*Alternate*	JJ_{ME}	*Critical Value*
$r \leq 0$	$r > 0$	72.80044[a]	24.27596	$r \leq 0$	$r = 1$	51.22548[a]	17.79730
$r \leq 1$	$r > 1$	21.57496[a]	12.32090	$r \leq 1$	$r = 2$	17.69679[a]	11.22480
$r \leq 2$	$r > 2$	3.878171	4.129906	$r \leq 2$	$r = 3$	3.878171	4.129906

[a] Value at 1% significance level
"r" symbolizes the number of cointegrating vectors

As we have seen the being of cointegration vectors among variables under consideration, we can proceed to formulate the ECM. The results of causality test are recorded in Table 3. Lag length selection criterion are provided in Table 4. Sequential modified LR test statistic (each test at 5% level), final prediction error, Akaike information criterion, Schwarz information criterion and Hannan-Quinn information criterion have been used for this purpose. We can see that unidirectional causality exist from growth in CO_2 emission to growth in fossil fuel consumption, economic growth to growth in fossil fuel consumption, and economic growth to growth in CO_2 emission.

TABLE 3
CAUSALITY TEST RESULTS

	Independent Variable			*Error Correction Term*
Dependent Variable	ΔFF	ΔEG	ΔCE	
ΔFF	-	33.45745[a]	79.34645[a]	0.020211[a]
ΔEG	4.477120	-	5.929292	-0.861451[a]
ΔCE	8.405823	11.88948[b]	-	-0.799292[a]

[a] Value at 1% significance level
[b] Value at 5% significance level

To set off this study, it is imperative to look into the long-run stability of the associations among the variables. For this purpose, we have carried out a series of diagnostic tests to check serial correlation (LM test), heteroscedasticity (White test) and stability test (Ramsey RESET test). The results those are recorded in Table 5, confirm the constancy of the model analyzing the associations among fossil fuel consumption, economic growth and CO_2 emission, in terms of having no serial correlation and heteroscedasticity among the variables, and the associations are stable in nature, along with high explanatory power.

TABLE 4
LAG LENGTH SELECTION CRITERIA

Lag	*LogL*	*LR*	*FPE*	*AIC*	*SC*	*HQ*
0	62.28295	NA	6.78e-06	-3.387597	-3.254282	-3.341577
1	223.4780	285.5454	1.14e-09	-12.08445	-11.55119*	-11.90037
2	234.4352	17.53155	1.03e-09	-12.19630	-11.26309	-11.87415
3	239.4244	7.127450	1.34e-09	-11.96711	-10.63395	-11.50690
4	242.7908	4.232060	1.97e-09	-11.64519	-9.912086	-11.04692
5	276.6093	36.71727*	5.30e-10*	-13.06339*	-10.93034	-12.32706*

TABLE 5
DIAGNOSTIC TEST RESULTS

Variables	R^2	*Adj.* R^2	*LM*	*White*	*Ramsey RESET*
FF	0.991530	0.991072	0.170870	0.161051	1.671982
EG	0.969589	0.967945	0.376619	0.351976	0.413365
CE	0.995600	0.995362	0.714497	0.871002	2.481871

Without considering the economic liberalization scenario, it can be said that for a developing nation like India, achieving the economic growth is the primary objective, and it for most of the times calls for overlooking sustainable development aspects. This economic growth is primarily driven by continuous consumption of fossil fuel, and demand for more growth entails consumption of more fossil fuel. This association is reflected by the unidirectional causal association from economic growth to growth in fossil fuel consumption, which is an extension of the results achieved by Paul and Bhattacharya (2004). This continuous economic growth brings forth environmental pressure in terms of CO_2 emission, which is reflected by the unidirectional causal association from economic growth to growth in CO_2 emission. However, unidirectional causal association from growth in CO_2 emission to growth in fossil fuel consumption indicates the missing feedback link of EKC hypothesis, which we have already discussed. Introduction of several environmental protection legislations and regulatory bodies in India like, the Forest (Conservation) Act, 1980, Air (Prevention and Control of Pollution) Act, 1981, several state-level water conservation acts indicate the significance of this causal association, which reflects the effect of environmental degradation on the driver of economic growth.

After Applying Interventions

In the previous section, we have observed and analyzed the causal associations between growth in fossil fuel consumption, economic growth, and growth in CO_2 emission, without applying any of the interventions. In this section, we will try to observe and analyze the causal associations between the aforementioned variables. Before proceeding with the same, nature of stationarity of interventions to be applied needs to be checked, for which unit root tests have been conducted. The results of unit root test are recorded in Table 6. It is evident that industrial value added (VA) and energy waste (EW) shows stationarity after first differentiation, and urbanization (U) after second differentiation.

TABLE 6
UNIT ROOT TEST RESULTS

	ADF	*PP*	*KPSS*
Level			

Intercept	VA	-2.080991	-2.092590	0.641612
	EW	2.078668	1.983462	0.773819
	U	-0.050929	-2.431774	0.779276
Intercept and Trend	VA	-3.774718[c]	-2.137560	0.150428
	EW	-2.744440	-2.744440	0.129813
	U	-3.106875	-3.053289	0.162470
First Difference				
Intercept	VA	-6.955758[a]	-6.955758[a]	0.185251
	EW	-5.320134[a]	-5.314678[a]	0.411684
	U	-1.729873	-1.735705	0.392286
Intercept and Trend	VA	-7.141064[a]	-7.117887[a]	0.053183
	EW	-5.759701[a]	-5.754942[a]	0.130744
	U	-1.198140	-1.198140	0.180611
Second Difference				
Intercept	U	-5.871812[a]	-5.871812[a]	0.259918
Intercept and Trend	U	-6.045956[a]	-6.046176[a]	0.066328

[a] Value at 1% significance level
[b] Value at 5% significance level
[c] Value at 10% significance level

Hence, it can be said that, in case of analysis considering first two interventions, variables are I(1) in nature, and for the third case, variables are I(2) in nature. After determining the order of integration among the variables and the interventions to be applied, it is needed to test the cointegration association between them. Like previous case, cointegration-testing methodology by Johansen and Juselius (1990) has been applied. The results are recorded in Table 7. Results show that brawny long run associations subsist among the variables and interventions. In all the three cases, null hypotheses of having no cointegrating vectors have been rejected by both the statistics, and they show that two cointegrating vectors are present between the variables and interventions in the first two cases and one cointegrating vector in the third case. Based on these results, we can proceed for further analysis.

TABLE 7
COINTEGRATION TEST RESULTS

Cointegration test using industrial value added (VA)							
Trace test				*Maximum Eigenvalue test*			
Null	*Alternate*	JJ_T	*Critical Value*	*Null*	*Alternate*	JJ_{ME}	*Critical Value*
$r \leq 0$	$r > 0$	2.56494[a]	40.17493	$r \leq 0$	$r = 1$	26.19012[a]	24.15921
$r \leq 1$	$r > 1$	6.37482[a]	24.27596	$r \leq 1$	$r = 2$	14.85490	17.79730
$r \leq 2$	$r > 2$	11.51992	12.32090	$r \leq 2$	$r = 3$	8.902062	11.22480
Cointegration test using energy waste (EW)							
Trace test				*Maximum Eigenvalue test*			
Null	*Alternate*	JJ_T	*Critical Value*	*Null*	*Alternate*	JJ_{ME}	*Critical Value*
$r \leq 0$	$r > 0$	52.11154[a]	40.17493	$r \leq 0$	$r = 1$	25.97830[a]	24.15921
$r \leq 1$	$r > 1$	26.13324[a]	24.27596	$r \leq 1$	$r = 2$	15.25316	17.79730
$r \leq 2$	$r > 2$	0.168605	4.129906	$r \leq 2$	$r = 3$	0.168605	4.129906
Cointegration test using urbanization (U)							
Trace test				*Maximum Eigenvalue test*			

Null	*Alternate*	JJ_T	*Critical Value*	*Null*	*Alternate*	JJ_{ME}	*Critical Value*
$r \leq 0$	$r > 0$	51.79920[a]	40.17493	$r \leq 0$	$r = 1$	31.83152[a]	24.15921
$r \leq 1$	$r > 1$	19.96769	24.27596	$r \leq 1$	$r = 2$	13.37663	17.79730
$r \leq 2$	$r > 2$	6.591052	12.32090	$r \leq 2$	$r = 3$	5.867035	11.22480

[a] Value at 1% significance level
"r" symbolizes the number of cointegrating vectors

As we have seen the being of cointegration vectors among variables under consideration, we can proceed to formulate the ECM. The results of causality test are recorded in. The results are recorded in Table 8. Lag length selection criterion are provided in Table 9. Like the pervious section, sequential modified LR test statistic (each test at 5% level), final prediction error, Akaike information criterion, Schwarz information criterion and Hannan-Quinn information criterion have been used for this purpose. We can see that causality associations, those we have found in the previous section, have changed largely. For the case of industrial value added intervention, bidirectional causal associations exist between growth in fossil fuel consumption and growth in CO_2 emission, and growth in fossil fuel consumption and economic growth, and unidirectional causal association exists from growth in CO_2 emission to economic growth. In case of energy waste intervention, bidirectional causal associations exist between growth in fossil fuel consumption and growth in CO_2 emission, and growth in fossil fuel consumption and economic growth. Considering intervention of urbanization, bidirectional causal association exists between growth in fossil fuel consumption and growth in CO_2 emission only. Now we will analyze these effects of interventions one by one.

Let us take the case of the intervention of industrial value added to start with. If the technological and industrial advancement aspects are left behind, it may prove out to be critical for a nation to depend only on legislative actions to mitigate environment degradation. One of the major aspects of economic liberalization was introduction of new technologies in Indian industrial domain, which accelerated economic growth. However, it acted as a double-edged sword considering India's atmospheric emission situate, i.e. catalyzing the growth in fossil fuel based electricity consumption, thereby increasing the atmospheric CO_2 emission level, and on the other hand, introducing several green technologies to resist emission level. Therefore, the feedback effect of atmospheric emission started to be visibly impactful on the driver of economic growth, i.e. fossil fuel consumption, along with the growth itself. This was indicated by the unidirectional causal association from growth in CO_2 emission to economic growth. During the first decade of the study, CO_2 emission per unit of GDP has an average of 0.247, whereas during last decade of the study, the same was 0.174. Therefore, it is quite visible that during first half of the study economic growth was causing growth in CO_2 emission, with a very less amount of feedback effect, which became predominant during the second half of the study, indicating the negative growth elasticity of emission. That is the reason the direction of causal association between economic growth and growth in CO_2 emission was altered after applying the intervention of industrial value added. Economic growth was being fueled by fossil fuel consumption, and prospective industrialization was demanding consumption of more fossil fuel. This was indicated by the bidirectional causal association between growth in fossil fuel consumption and economic growth. Hence, legislative actions and technological advancements were acting together towards mitigation of the environmental damages being caused by continuous consumption of fossil fuel. Moreover, during this period, carbon trading in India was gaining prominence, due to which several industries started to keep their carbon footprint intact. This phenomenon has been indicated by the bidirectional causal association between growth in fossil fuel consumption and growth in CO_2 emission.

TABLE 8
CAUSALITY TEST RESULTS

Causality analysis using industrial value added (VA)

	Independent Variable				Error Correction Term
Dependent Variable	ΔFF	ΔEG	ΔCE	ΔVA	
ΔFF	-	6.043383[a]	15.44336[a]	3.253523	-0.057634[a]
ΔEG	5.363790[b]	-	6.511133[a]	1.316253	-0.039150[a]
ΔCE	5.902941[b]	0.664738	-	3.668833	-0.105296[a]
ΔVA	15.37052[a]	0.148082	11.35078[a]	-	-0.203438[a]
Causality analysis using energy waste (EW)					
	Independent Variable				Error Correction Term
Dependent Variable	ΔFF	ΔEW	ΔEG	ΔCE	
ΔFF	-	1.874914	5.491500[c]	16.64088[a]	0.026368[a]
ΔEW	1.192637	-	8.083179[b]	1.392324	0.009243[a]
ΔEG	5.886544[c]	4.151562	-	1.267882	0.140973[a]
ΔCE	7.698427[b]	1.851769	3.358084	-	-0.008365[a]
Causality analysis using urbanization (U)					
	Independent Variable				Error Correction Term
Dependent Variable	ΔFF	ΔCE	ΔEG	ΔU	
ΔFF	-	22.20717[a]	1.456352	5.394364[b]	0.057529[a]
ΔCE	9.432851[a]	-	2.330795	8.479220[a]	-0.168497[a]
ΔEG	3.361662	2.125647	-	6.708732[a]	0.255174[a]
ΔU	4.546411	2.449022	3.889956	-	-0.005942[a]

[a] Value at 1% significance level
[b] Value at 5% significance level
[c] Value at 10% significance level

Now, let us look at the impact of the second intervention, i.e. energy waste. By far, fossil fuel based energy consumption amounts to nearly 73 percent of the total energy consumption in India. Hence, for India, fossil fuel consumption is the primary reason for greenhouse blanket formation. From this perspective, it can be said that, whenever energy conservation practices are considered, it majorly poses impacts on the driver of economic growth and the externalities caused by growth. In this case, the externality is negative in nature, and is having the form of CO_2 emission. Therefore, to have a control over this negative externality, it is required to have energy efficiency, which can be indicated by lowering of combustible energy waste, the intervention used in this case. Considering India, formation of Petroleum Conservation Research Association (PCRA) in 1977, and Bureau of Energy Efficiency in 2001 are two major steps in bringing forth energy efficiency in Indian industrial scenario. Due to this, we can see that 10.86 percent growth rate of CO_2 emission per unit of fossil fuel consumption during first half of the study had come down to 0.84 percent during second half of the study, indicating a nearing zero fossil fuel consumption elasticity of emission. This phenomenon has been indicated by the bidirectional causal association between growth in fossil fuel consumption and growth in CO_2 emission. Moreover, we can also see that the 2.16 percent average growth rate of fossil fuel consumption during first half of the study has come down to 1.37 percent during second half of the study. Indicating energy efficiency, the diminishing growth of fossil fuel consumption can have a possible causal effect on economic growth, due to which it became imperative to fuel economic growth via alternative and nuclear energy resources, as fossil fuel consumption per unit of GDP has come down to 2.99 percent in 2010 from 8.49 percent in 1971. This phenomenon has been addressed by the bidirectional causal association between growth in fossil fuel consumption and economic growth.

TABLE 9
LAG LENGTH SELECTION CRITERIA

Lag length selection using industrial value added (VA)						
Lag	*LogL*	*LR*	*FPE*	*AIC*	*SC*	*HQ*
0	144.1993	NA	4.87e-09	-7.788853	-7.612906	-7.727443
1	321.7469	305.7763	6.21e-13	-16.76371	-15.88398*	-16.45666
2	346.0661	36.47882*	4.05e-13*	-17.22589*	-15.64237	-16.67320*
3	357.7530	14.93326	5.65e-13	-16.98628	-14.69897	-16.18795
4	377.5353	20.88132	5.54e-13	-17.19640	-14.20531	-16.15243

Lag length selection using energy waste (EW)						
Lag	*LogL*	*LR*	*FPE*	*AIC*	*SC*	*HQ*
0	142.6689	NA	5.30e-09	-7.703831	-7.527884	-7.642420
1	357.3252	369.6858	8.60e-14	-18.74029	-17.86056*	-18.43324
2	378.3599	31.55201*	6.74e-14*	-19.01999*	-17.43647	-18.46730*
3	391.1091	16.29068	8.86e-14	-18.83939	-16.55209	-18.04106
4	409.4867	19.39855	9.38e-14	-18.97148	-15.98039	-17.92751

Lag length selection using urbanization (U)						
Lag	*LogL*	*LR*	*FPE*	*AIC*	*SC*	*HQ*
0	198.0480	NA	3.27e-10	-10.48908	-10.31493	-10.42769
1	431.9886	404.6539	2.52e-15	-22.26965	-21.39889	-21.96267
2	473.0346	62.12368*	6.73e-16*	-23.62349*	-22.05611*	-23.07092*
3	482.4400	12.20162	1.05e-15	-23.26703	-21.00303	-22.46886

Finally, we will look at the impacts of the third intervention, i.e. urbanization. Once economic liberalization was set in, industrialization gained pace in India, due to which migration of rural populace towards urban areas was taking place. Attributing to this, urban infrastructure was being faced with huge pressure in terms of high demand of energy and high atmospheric emission. This was the time, when several slum areas were formed around the industrial belts in the form of shadow cities, which did not have proper sanitation facilities, and the inhabitants used to burn firewood and coal for their daily cooking purpose. Therefore, their daily existence called for direct and derived demand of fossil fuel consumption. However, their lifestyle pattern resulted in increase in CO_2 emission in the industrial regions of India, and this was causing harm to the hygiene level of labor force in terms of increasing respiratory diseases. To reconcile this, Maharashtra government passed Slum Rehabilitation Act, 1995, which was an extension of Maharashtra Slum Areas (Improvement, Clearance and Redevelopment) Act, 1971. Primary focus of this act was improvement of the lifestyle of slum dwellers. This entire phenomenon has been addressed by the bidirectional causal association growth in fossil fuel consumption and growth in CO_2 emission.

Last but not the least, it is imperative to look into the long-run stability of the associations among the variables. For this purpose, we have carried out a series of diagnostic tests to check serial correlation (LM test), heteroscedasticity (White test) and stability test (Ramsey RESET test), which we have conducted in the previous section as well. The results those are recorded in Table 10, confirm the constancy of the model analyzing the associations among the variables under consideration and the applied interventions, in terms of having no serial correlation and heteroscedasticity among the variables, and the associations are stable in nature, along with high explanatory power.

TABLE 10
DIAGNOSTIC TEST RESULTS

Variables	R^2	*Adj.* R^2	*LM*	*White*	*Ramsey RESET*
Diagnostic test using industrial value added (VA)					
FF	0.991827	0.991146	0.495824	1.104635	2.763048
EG	0.974500	0.972375	0.172943	1.199927	0.805265
CE	0.995732	0.995376	0.006168	0.324445	0.005513
VA	0.785456	0.767577	0.479902	1.821885	1.942132
Diagnostic test using energy waste (EW)					
FF	0.991558	0.990855	1.936786	1.089764	2.099352
EW	0.979841	0.978161	1.924509	0.625894	0.542318
EG	0.969700	0.967175	0.255680	0.241500	0.048571
CE	0.996203	0.995887	0.242843	1.021475	0.161094
Diagnostic test using urbanization (U)					
FF	0.991593	0.990892	0.208022	1.158355	0.059731
CE	0.996742	0.996471	1.051292	1.153361	2.457134
EG	0.981339	0.979784	0.153274	0.362476	1.344177
U	0.995146	0.994741	0.584963	1.910610	1.041783

TABLE 11
OVERALL RESULTS OF CAUSALITY ANALYSIS

Pair-wise variables	*With no intervention*	*With Value Added*	*With Energy Waste*	*With Urbanization*
FF & CE	FF <= CE	FF ⇔ CE	FF ⇔ CE	FF ⇔ CE
FF & EG	FF <= EG	FF ⇔ EG	FF ⇔ EG	NA
EG & CE	EG => CE	EG <= CE	NA	NA

CONCLUSION

So far, we have analyzed the impacts of economic liberalization associated interventions on the causal association among fossil fuel consumption, economic growth, and CO_2 emission, for the period of 1971-2010. The final consolidated results are recorded in Table 11. We have visualized that the causal associations between the variables depend largely on the contextual interventions, which are industrial value added, combustible energy waste, and urbanization in this case for Indian economic liberalization context. Analysis of missing feedback link for EKC hypothesis has been carried out by researchers several times and in diverse contexts. However, in the literature of ecological / environmental economics, it has hardly been tried to encapsulate the changes in aforementioned feedback mechanism after incorporating contextual interventions, which is the primary focus of this paper. From that perspective, it can possibly add substantive value to existing body of knowledge in terms of pre-and-post analysis of contextual variables, while considering any cointegration and causality analysis, and beyond.

From the environmental degradation perspective of India, this paper can bring forth significant policy implications, as the effects of economic liberalization of India has been captured here both in terms of data and parametric interventions. Prior to economic liberalization set in, environmental degradation in India was handled primarily by legislative actions, as due to lack of modern technologies it was tough for the industries to combat this issue in a more effective manner. The problems became more prevalent once the economic liberalization was set in, because it harnessed several problems, namely rapid industrialization, rural-urban migration, formation of slum areas in industrial belts, high demand of energy and fossil fuel, and high level of atmospheric emission. As to keep their carbon footprint intact, developed nations most of the times try to dump their obsolete and polluting technologies in developing and underdeveloped nations at a low cost, which deems as a lucrative alternative for the latter parties. In doing so, developing and underdeveloped nations worsen their carbon footprints by causing more harm to the environmental aspects, through technology-driven economic growth. Hence, an endogenous and green growth is desired, rather than exogenous technology-driven growth. As India is gradually moving towards commercialization of nuclear power and thriving to discover more alternative energy resources, it can be expected that continuous evolution and improvement of technology, legislative actions by government, and increasing awareness of citizens regarding protection of their ecological surrounding, it can be expected that, India can achieve the desired level of carbon footprint very soon. A number of social organizations and non-governmental organizations (NGO) are coming forward and taking initiatives at regional or state level for environmental protection. These initiatives need to be replicated across the nation by the support of public-private partnership, as it is not the sole responsibility of Indian government to combat this predicament. Continuous involvement of citizens is also required, as this may have the possibility to create an unparallel level of ecological awareness. From EKC hypothesis, we know that environmental degradation starts falling at a particular level of income growth, which is catalyzed by the awareness level of the citizens, and if government can involve the people and industry in replicating the ecological protection initiatives nationwide, only then we can achieve the aspiration of a clean environment.

REFERENCES

Antle, J. M. & Heidebrink, G. (1995). Environment and Development: Theory and International Evidence. *Economic Development and Cultural Change*, 43, (3), 603-625.

Asafu-Adjaye, J. (2000). The relationship between energy consumption, energy prices and economic growth: time series evidence from Asian developing countries. *Energy Economics*, 22, (6), 615-625.

Beenstock, M., Goldin, E. & Nabot, D. (1999). The demand for electricity in Israel. *Energy Economics*, 21, (2), 168-183.

Beirle, S., Platt, U., Wenig, M. & Wagner, T. (2003). Weekly cycle of NO_2 by GOME measurements: A signature of anthropogenic sources. *Atmospheric Chemistry and Physics*, 3, (6), 2225-2232.

Chang, C. C. (2010). A multivariate causality test of carbon dioxide emissions, energy consumption and economic growth in China. *Applied Energy*, 87, (11), 3533-3537.

Cheng, B. S. (1999). Causality between Energy Consumption and Economic Growth in India: An Application of Cointegration and Error-Correction Modeling. *Indian Economic Review*, 34, (1), 39-49.

De Bruyn, S. M., van den Bergh, J. C. & Opschoor, J. B. (1998). Economic Growth and Emissions: Reconsidering the Empirical Basis of Environmental Kuznets Curves. *Ecological Economics*, 25, (2), 161-175.

Dickey, D. A. & Fuller, W. A. (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, 49, (4), 1057-1072.

Dickey, D. A., Jansen, D. W. & Thornton, D. L. (1991). A Primer on Cointegration with an Application to Money and Income. *Federal Reserve Bank of St. Louis Review*, 73, (2), 58-78.

Dinda, S. (2004). Environmental Kuznets Curve Hypothesis: A Survey. *Ecological Economics*, 49, (4), 431-455.

Ebohon, O. J. (1996). Energy, Economic Growth and Causality in Developing Countries: A Case Study of Tanzania and Nigeria. *Energy Policy*, 24, (5), 447-453.

Engle, R. F. & Granger, C. W. J. (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica*, 55, (2), 251-276.

Frankel, J. A. & Rose, A. K. (2005). Is trade good or bad for the environment? Sorting out the causality. *Review of Economics and Statistics*, 87, (1), 85-91.

Ghosh, S. & Basu, S. (2006). Coal and gas consumption with economic growth: co-integration and causality evidences from India. *Journal of Resources, Energy and Development*, 3, (1), 13-20.

Granger, C. W. J. (1969). Investigating Causal Relations by Econometric and Cross-Spectral Methods. *Econometrica*, 37, (3), 424-438.

Grossman, G. M. & Krueger, A. B. (1991). *Environmental Impacts of a North American Free Trade Agreement (No. w3914)*. National Bureau of Economic Research.

Halicioglu, F. (2009). An Econometric Study of CO_2 Emissions, Energy Consumption, Income and Foreign Trade in Turkey. *Energy Policy*, 37, (3), 1156-1164.

Hayami, Y. & Ruttan, V. W. (1970). Agricultural Productivity Differences among Countries. *The American Economic Review*, 60, (5), 895-911.

Hill, R. J. & Magnani, E. (2002). An Exploration of the Conceptual and Empirical Basis of the Environmental Kuznets Curve. *Australian Economic Papers*, 41, (2), 239-254.

Hondroyiannis, G., Lolos, S. & Papapetrou, E. (2002). Energy consumption and economic growth: assessing the evidence from Greece. *Energy Economics*, 24, (4), 319-336.

Intergovernmental Panel on Climate Change. (2007). *Climate Change 2007: Synthesis Report*, Geneva, Switzerland: IPCC.

Jacobson, M. Z. (2005). Correction to “Control of fossil-fuel particulate black carbon and organic matter, possibly the most effective method of slowing global warming”. *Journal of Geophysical Research: Atmospheres (1984-2012)*, 110(D14).

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, 12, (2), 231-254.

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica*, 59, (6), 1551-1580.

Johansen, S. & Juselius, K. (1990) .Maximum likelihood estimation and inference on cointegration-with applications to the demand for money. *Oxford Bulletin of Economics and Statistics*, 52, (2), 169-210.

Kander, A. (2002). *Economic Growth, Energy Consumption and CO_2 Emissions in Sweden: 1800-2000 (Vol. 19)*, Lund: Almqvist & Wiksell International.

Kijima, M., Nishide, K. & Ohyama, A. (2010). Economic Models for the Environmental Kuznets Curve: A Survey. *Journal of Economic Dynamics and Control*, 34, (7), 1187-1201.

Klump, R. & Cabrera, C. M. (2008, November). *Biased Technological Change in Agriculture: The Hayami-Ruttan Hypothesis Revisited*. Paper presented at the Dynamics, Economic Growth, and International Trade – XIII, Manila, Philippines.

Kraft, J. & Kraft, A. (1978). On the Relationship between Energy and GNP. *Journal of Energy and Development*, 3, (2), 401-403.

Kuznets, S. (1955). Economic Growth and Income Inequality. *The American Economic Review*, 45, (1), 1-28.

Kwiatkowski, D., Phillips, P. C., Schmidt, P. & Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root. *Journal of Econometrics*, 54, (1), 159-178.

Manabe, S. & Wetherald, R. T. (1975). The Effects of Doubling the CO_2 Concentration on the Climate of a General Circulation Model. *Journal of the Atmospheric Sciences*, 32, (1), 3-15.

Masih, A. M. M. & Masih, R. (1996). Energy Consumption, Real Income and Temporal Causality: Results from a Multi-Country Study based on Cointegration and Error-Correction Modeling Techniques. *Energy Economics*, 18, (3), 165-183.

Mozumder, P. & Marathe, A. (2007). Causality Relationship between Electricity Consumption and GDP in Bangladesh. *Energy Policy*, 35, (1), 395-402.

Nordhaus, W. D. (1977). Economic Growth and Climate: The Carbon Dioxide Problem. *The American Economic Review*, 67, (1), 341-346.

Ozturk, I. (2010). A literature survey on energy-growth nexus. *Energy Policy*, 38, (1), 340-349.

Paul, S. & Bhattacharya, R. N. (2004). Causality between energy consumption and economic growth in India: a note on conflicting results. *Energy Economics*, 26, (6), 977-983.

Phillips, P. C. & Perron, P. (1988). Testing for a unit root in time series regression. *Biometrika*, 75, (2), 335-346.

Prospero, J. M. (2002). The chemical and physical properties of marine aerosols: An introduction. In Gianguzza, A., Pelizzetti, E. & Sammartano, S. (Eds.), *Chemistry of Marine Water and Sediments* (35-82), Berlin, Heidelberg: Springer.

Shafik, N. & Bandyopadhyay, S. (1992). *Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence (Vol. 904)*, World Bank Publications.

Shiu, A. & Lam, P. L. (2004). Electricity Consumption and Economic Growth in China. *Energy Policy*, 32, (1), 47-54.

Sinha, A. & Mehta, A. (2014). Causal Analysis of India's Energy-led Growth and CO_2 Emission (1960-2010). *Indian Journal of Economics and Business*, 13, (1), 81-89.

Soytas, U. & Sari, R. (2003). Energy Consumption and GDP: Causality Relationship in G-7 Countries and Emerging Markets. *Energy Economics*, 25, (1), 33-37.

Soytas, U., Sari, R. & Ewing, B. T. (2007). Energy Consumption, Income, and Carbon Emissions in the United States. *Ecological Economics*, 62, (3), 482-489.

Toda, H. Y. & Phillips, P. C. (1993). Vector autoregressions and causality. *Econometrica: Journal of the Econometric Society*, 61, (6), 1367-1393.

Wetherald, R. T. & Manabe, S. (1988). Cloud feedback processes in a general circulation model. *Journal of the Atmospheric Sciences*, 45, (8), 1397-1416.

Yu, E. S. H. & Hwang, B. K. (1984). The Relationship between Energy and GNP: Further Results. *Energy Economics*, 6, (3), 186-190.

Yu, E. S. H. & Jin, J. C. (1992). Cointegration tests of energy consumption, income, and employment. *Resources and Energy*, 14, (3), 259-266.

Zhang, X. P. & Cheng, X. M. (2009). Energy Consumption, Carbon Emissions, and Economic Growth in China. *Ecological Economics*, 68, (10), 2706-2712.